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THE VALUE OF CROP ROTATIONS FOR SOIL AND WATER CONSERVATION

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In planning crop rotations for soil and water conservation, full consideration must be given to the natural forces and resistances to be dealt with. The natural distribution of rainfall, its classification as to intensity, frequency of occurrence, etc., must be considered. Crop rotations--to be most effective for soil and water conservation--must be adjusted and fitted to the specific requirements of the local climate, soil, farmer, and farm enterprise.

Before we can develop highly effective soil and water conservation practices--and this applies particularly to crop rotations--for a problem area, the erosion process involved must be well understood. An analysis of the rainfall intensities and frequencies, the erosiveness of the soil by wind or water, drought hazards, length of growing season, etc., must be made before prescribing specific rotations.

Crop rotations, to be effective, must therefore be designed to protect the soil against those destructive processes. They must be designed so as to provide a good surface cover of either living vegetation or crop residue at all times and especially for those periods when the destructive rains or winds are expected to occur with greatest frequency. This calls for a close study and consideration of the climatic record and an analysis of rainfall, drought, wind velocities, etc., for each problem area, before designing crop rotations and supporting soil and water conservation practices.

In this presentation, I show a limited amount of experimental data and point out many of the fundamental reasons why one cropping system proved better than others in conserving soil and water. The data which are presented in the first part of this discussion show the soil and water losses from different crop rotations and systems of cropping, along with a system of evaluating a number of rotations on the basis of their efficiency in controlling erosion.

In the second part I show the effect of erosion on the depletion of organic matter in the soil and also the relationship of this organic matter that is contained in the topsoil to the yield of corn. The data will show that the corn yields begin to decline with the loss of the first inch of soil and continue until all the topsoil is removed. The data show further that while the yields can be improved by the addition of soil amendments and fertilizer treatments, this improvement will not replace the loss encountered through the removal of topsoil by erosion.

In discussing crop rotations, I think it best to first define what is meant by "good crop rotations." <u>Good crop rotations provide for the systematic cropping of the land in a way that will stabilize the soil, maintain or improve fertility, yields, and the nutrient value of crops. The rate of soil loss must be reduced below the maximum rate consistent with permanent use of the land, and at the same time the land must produce economic returns. Obviously, the type of rotation that should be used on any given piece of farm land will depend on the characteristics of the land.</u>

If the land is very steep, only sod crops or trees can protect it against serious erosion. If it is gently rolling, rotations that provide a sod cover one, two, or more years out of 3 to 5 years will keep the soil from deteriorating. The data which follow show that any cropping system--to be fully effective--must be supplemented with other conservation practices, such as good seed, timely operations, contouring, terracing, application of plant food, amendments, return of crop residues and manures, strip cropping, etc.,--according to the needs of the particular field or farm.

That good cropping systems or rotations have not been and are not now being generally practiced in many of our important agricultural areas is obvious from the fact that from 1935 to 1939 intertilled crops were grown on 46 percent of all the land used for crops in five North Central

States (7)[1]--which include Ohio, Indiana, Illinois, Iowa, and Missouri. In 1943 and 1944 the corresponding percentage was 52.1. In Iowa the percentages of all cropland on which intertilled crops were grown in the two periods were 45.7 and 52.5. In Illinois they were 50 and 56.9 percent and in Ohio, 38.2 and 45.5. It is obvious that with such proportions of all the cropland under clean tillage in 1943 and 1944, the best possible sequence of crops would not have made possible the use of soil-conserving rotations or prevented exploitation of our soil resources.

For example, at Bethany, Mo. (3), a Shelby loam soil cropped annually to corn for 10 years lost 27.2 percent of the rainfall as runoff and on an average lost annually 50.9 tons of soil per acre--equivalent to more than one-third of an inch. Adjacent land cropped to a 3-year rotation of corn, wheat, and hay lost 16.5 percent of the rainfall as runoff and only 7.51 tons of soil per acre annually. Continuous covers of alfalfa and bluegrass permitted only 6.7 and 8.1 percent runoff, respectively, with only a trace (0.15 ton per acre) of soil loss.

At Zanesville, Ohio (1), the average annual soil loss from the continuous corn plot was 99.3 tons per acre--compared with 13.4 tons per acre for the 4-year rotation. The soil loss from first-year meadow was 0.58 ton per acre and for second-year meadow it was 0.22 ton. From improved grass the loss was but 0.028 ton of soil, with 4.75 percent of the rainfall lost as runoff. Obviously, the loss from the 4-year rotation was yet too high (13.4 tons per acre), showing that supplemental treatments, such as contouring, fertilization, and residue management, were needed.

Similar results were obtained on Marshall silt loam near Clarinda, Iowa (5). For the 10-year period 1932-42, land cropped annually to corn lost 3.2 times as much of the precipitation and 5.32 times as much soil as land in the 3-year rotation of corn-oats-clover. Low runoff and only a trace of soil were recorded for plots in alfalfa and bluegrass. A marked cumulative influence of these crops in reducing erosion became evident when the land was plowed and planted to corn.

Much of the benefit derived from growing sod crops is due to the influence that these crops have upon aggregation or the binding together of soil particles. The improved structure accompanying this aggregation permitted rapid movement of water and air into and within the soil and consequently prevented excessive runoff.

The Marshall silt loam plots on which alfalfa and bluegrass had been grown were found to have [illegible] and [illegible] percent [illegible] aggregation, respectively, than plots on which corn had been grown annually. The [illegible] in aggregation in the plots formerly in alfalfa and bluegrass [illegible] still evident when these plots had been cropped to corn for 3 years. The losses of water and soil from [illegible] they were in corn--1943 to 1945--were markedly less than [illegible] where a single crop of corn followed one of clover. This shows that land [illegible] in a sod crop two or more years at a time in order to secure better aggregation [illegible] organic matter, and thereby better condition and stabilize the soil.

Counts were made at Bethany, Mo. (5), of the number of drops of water falling [illegible] centimeters that were required to disperse an average aggregate about the size of a small pea and wash it through a 20-mesh screen. These tests were made on [illegible] aggregates taken from the surface inch of soil on each of the control plots that were under varying cropping and cultural practices.

It was found that it required but 6.2 drops of water falling 30 centimeters to entirely disperse the average aggregate from soil that had been cropped annually to corn. This is contrasted to the requirement of 37.7 drops to disperse aggregates taken from first-year meadow; 41.2 drops for aggregates after second-year meadow; and 40.2 drops for aggregates taken from land that had been in alfalfa for 13 years.

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[1] Italic numbers in parentheses refer to Literature Cited at end of the report.

All over the country we can observe the superior physical condition of soils under sod. Where sod has been turned under for corn, more rapid infiltration and percolation and less runoff and erosion occur. Also, microbial activity and aeration are greater than where corn has been grown annually.

The reduction in the amount of nitrogen or organic matter when land is cropped annually to corn is shown in table 1, page 4 (6). This table gives the annual yields of crops and of digestible nutrients produced under different cropping systems; also nitrogen content of the plow depth of soil at the end of the experimental period 1921-35 as reported by the Ohio Agricultural Experiment Station at Wooster.

Where corn had been grown annually for 15 years, only 1,425 pounds of nitrogen remained, compared with 2,075 pounds for a 2-year rotation; 2,263 for a 3-year rotation; and 2,450 and 2,487 pounds for 4- and 5-year rotations, respectively.

It will be noted further that the per-acre yield of corn increased as the length of rotation increased--especially the length of time the land was occupied by hay. Attention is also directed to the fact that the total digestible protein as well as the total digestible nutrients produced with the 4- and 5-year rotations was markedly higher than for continuous corn or for the 2- and 3-year rotations. Still we have the common complaint that we can't afford to cut our corn acreage. The relation between the nitrogen content of the plow depth and the yield of corn is very similar to that which we found from a cooperative study conducted in 1939 and 1940. We found for Indiana, Ohio, Iowa, and Missouri a direct relationship between the organic matter content of the soil and the per-acre yield of corn. In like manner, as I will show in a later table (table 10), we found a direct relationship between the depth of topsoil and corn yield.

The runoff and soil losses from plots in each crop of a 4-year rotation and in continuous cotton at Statesville, N. C. (2), are shown in table 2, page 4. Here again attention is called to the marked difference in both runoff and soil loss, especially in the soil loss from different crops in the rotation. More striking, however, is the excessive runoff and soil loss that occurs under continuous cotton. From an efficiency standpoint, however, this rotation was but 53.7 percent effective. Obviously, this rotation as practiced here did not give adequate protection to the soil.

Table 3, page 5, shows how the soil and water losses from plots in peas grown in a 3-year rotation at Marcellus, N. Y.,[2] were markedly affected by supplemental treatment. For example, where a low rate application of manure was plowed under preceding the planting of peas, the soil loss amounted to 18.79 tons per acre, whereas a heavy rate turned under gave a soil loss of 12.66 tons per acre. By using the low rate as a top dressing (that is, leaving it on the surface) the soil loss was 3.31 tons and the water loss was about one-half that which took place when the manure was plowed under. Where the heavy manure application was made as a top dressing, only 0.66 ton of soil was lost. This represents but 3.5 percent as much soil as was lost from the same crop where a low rate of manuring was applied and turned under. It was 5.2 percent of the loss that occurred where a high rate application of manure was turned under. These results point out the need for combining practices so that one supports another.

This point is further emphasized by the data presented in table 4, page 5, which show the marked effect of mulch or crop residues on rate of runoff from corn and soybeans, Urbana, Ill., April-May 1943 (8).[3]

In this experiment water was applied as simulated rainfall at the rate of 1.75 inches per hour and the runoff was measured at the end of 30, 60, and 240 minutes. The data show that for both corn and soybeans, the addition of either wheat straw or soybean residue to the surface soil that had previously grown soybeans resulted in markedly reducing the water loss for each time interval.

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[2] LAMB, J. R. Annual Progress Report, 1947. (Arnot, Marcellus, and Geneva, N. Y., Expt. Sta.) 1947. (Typewritten.)

[3] VAN DOREN, C. A. Annual Report for Calendar Year 1944. (Urbana and Dixon Springs Soil Conserv. Expt. Stas.) 1944. (Typewritten.)

TABLE 1.--*Average annual yields of crops and of digestible nutrients produced under different cropping systems, also nitrogen content of cropped soil at end of period 1921-35, Ohio Agricultural Experiment Station, Wooster*

Item		Corn annually	2-yr. rotation	3-yr. rotation	4-yr. rotation	5-yr. rotation
Corn	Bushels	27.0	64.0	77.2	70.6	82.1
Oats	"	-	-	-	-	62.9
Wheat	"	-	32.4	38.3	38.4	-
Alfalfa						
First Yr.	Tons	-	-	2.74	3.17	2.63
Second Yr.	"	-	-	-	4.10	3.59
Third Yr.	"	-	-	-	-	3.92
Total Digestible Proteins[1]	Pounds	108	237	382	520	533
Total Digestible Nutrients	"	1,215	2,250	2,710	3,092	3,055
Total Nitrogen[2]		1,425	2,075	2,263	2,450	2,487

[1]Calculated on basis of harvested grain and hay.
[2]Nitrogen in plow depth.

TABLE 2.--*Runoff and soil losses from plots in each crop of 4-year rotation and in continuous cotton, Conservation Experiment Station, Statesville, N. C.*[1]

Crop	No. of crops	Rainfall	Runoff	Soil Loss
		Inches	*Percent*	*Tons/A.*
Crops in Rotation				
Corn	8	47.80	10.7	28.69
Wheat and Lespedeza	7	48.20	13.5	5.61
Lespedeza	9	47.48	5.3	1.52
Cotton	8	47.80	10.4	21.82
Ave. 4-Yr. Rotation		47.80	10.0	14.44
Continuous Cotton	8	47.80	12.4	31.22

[1]Data for period 1931-38.

TABLE 3.--*Soil and water losses from plots in peas in 3-yr. rotation with different treatments, Marcellus, N. Y., 1947*[1]

Treatments	Water loss	Soil loss
	Inches	*Tons per acre*
Low rate manure, plowed under	1.73	18.79
High rate manure, plowed under	1.62	12.66
Low rate manure, top dressed	.86	3.31
High rate manure, top dressed	.77	.66

[1]Soil and water losses for period June 30-December 31, 1947.

TABLE 4.--*Effect of mulch or crop residue on rate of runoff from corn and soybeans, Urbana, Ill., April-May 1943*[1]

Crop and mulch	30 minutes (2)	60 minutes (2)	240 minutes (2)
	Inches	*Inches*	*Inches*
Soybeans--unmulched	1.43	1.55	1.60
Soybeans--Wheat straw	.21	.32	.47
Soybeans--Residue	.27	.43	.94
Corn--unmulched	1.05	1.35	1.51
Corn--Wheat straw	.07	.09	.49
Corn--Stover residue	.11	.15	.65

[1]Simulated rainfall applied at rate of 1.75" per hour.
[2]Rate of runoff in inches per hour at indicated time intervals.

The runoff, for example, from soybean land which had received the mulch of wheat straw was only about 11 percent for the 30-minute period, 18 percent for the 60-minute period, and a little less than 27 percent for the 240-minute period. More than 90 percent of the rainfall was lost as runoff where the land was unmulched and no crop residue remained. In like manner, the addition of wheat straw as a mulch to cornland reduced the runoff from 1.35 inches at the end of 60 minutes to 0.09 inch. At the end of 240 minutes the runoff from unmulched corn was 1.51 inches, compared with 0.49 inch where a straw mulch was used.

Table 5, page 7, shows the data on soil renewal plots at Bethany, Mo. (4), Soil and Water Conservation Experiment Station. It will be noted in this table that the organic matter level in the exposed subsoil is markedly less than that contained in the moderately eroded surface soil. Even after 11 years of cropping and the return of considerable crop residues and manure, the organic matter level had been only slightly increased.

If we could assume that these rates of change in organic matter on these desurfaced plots will continue, it will require 66 years of cropping to a 4-year rotation of corn-oats-and 2 years of hay to build the organic matter up to the level contained in the topsoil as it was tested in 1930. By liming and fertilizing and seeding to a grass-legume mixture (plot 7) and allowing all the organic matter to fall back on the desurfaced soil, the organic matter equivalent to that contained in the original topsoil could be attained in a little less than 30 years.

Exposed subsoils, however, are usually more difficult to cultivate, allow more runoff, have less plant food, and make less effective the rainfall with which to make a crop. Unless erosion and runoff are controlled, much of the plant food applied as fertilizer may be lost. I should like to point out that the cultural operations on these soil renewal plots were carefully performed and the runoff and soil losses were held to a minimum. Under field conditions, plowing of severely eroded lands or exposed subsoils average much shallower, and the runoff and soil losses are much greater.

Obviously, the rates of change in organic matter ("Soil Conservation," June 1944) recorded for the desurfaced plot are greater than would occur under normal field conditions. Again it should be pointed out that most investigators have found that cultivated soils accumulate organic matter at a much slower rate as the organic matter level rises. In other words, we would expect it to take a great deal more time and be much more difficult to increase the organic matter content of a soil at a given location from 2.5 percent to 3.5 percent than to increase it from 1.5 percent to 2.5 percent. It should be pointed out, for example, that plot 1, the normal surface soil, contained 3.02 percent organic matter in 1932 but without treatment declined to 2.84 percent--a loss of 0.18 percent or 1.8 tons per acre in 11 years under a 4-year rotation. These observations would indicate that the accumulation of organic matter in these soil renewal plots will become increasingly slower, and the time required to bring the organic matter above 3 percent (that found in the topsoil removed in 1932) will be much greater than that indicated above. There is a big question, I think, as to whether it can ever be raised to this point while cropped to cultivated crops. If left in grass and legume, as in plot 7, it is possible that in time the organic matter would be restored.

A glance at the corn yields shows that the yield for a 4-year rotation on exposed subsoil is less than half the yield of corn on the untreated, moderately eroded topsoil. With the addition of soil amendments, fertilizer, manure, and turning under sweet clover on plot 6, a fairly good yield of corn was secured in 1942. Since the organic matter level, however, on this plot had only increased to 2.26 percent, we can expect this type of yield to occur only occasionally.

In table 6, page 7, I have set up an efficiency rating for different cropping systems, based upon the soil loss that occurred from different crops and cropping systems with and without supporting practices, at Bethany, Mo. Continuous corn grown on moderately eroded soil without supporting practices accomplished no conservation. The efficiency of the particular cropping system with supporting practice or practices was secured by the use of the following formula:

CORRECTIONS TO SCS-TP-83 (The Value of Crop Rotations for Soil and Water Conservation) by R. E. Uhland, July 1949

Page 2. Third paragraph from the bottom, line 6 should read as follows: 'plots where corn was grown annually for 3 years after 1 year of clover. This shows that land . . .'

Page 6. The last paragraph should read: 'In *table 6* the efficiency of cropping systems at Bethany, Mo., with and without supporting practices for controlling erosion, are shown. The efficiencies are based upon a standard of efficiency shown at right. By using the standard of efficiency shown in this table, the efficiency of cropping systems at different locations throughout the country may be compared.'

Page 7. The following table should replace *table 6* on the lower half of *page 7*.

TABLE 6.--*Efficiency of cropping systems, Bethany, Mo., with and without supporting practices for controlling erosion--based upon standard of efficiency shown at right*

Efficiency of farming systems, Bethany, Mo.				Standard efficiency	
Cropping system[1] on 8% slope	Treatment	Time to erode 7 ins.	Efficiency percent	Time to erode 7 ins.	Efficiency percent
		Yrs.		*Yrs.*	
Corn - annually	None	18.8	18.8	-10	0
Corn - annually	16 Tons Manure	27.8	23.9	10	10
Corn-Wheat-Hay	None	108.2	43.5	20	20
Corn-Wheat-Hay	Lime + Phosphate	137.0	47.1	40	30
Corn-Oats-Hay	Lime + Phosphate	167.8	50.5	80	40
Corn-Oats-Hay	Lime + Phosphate + Manure	413.5	62.9	160	50
Corn-Soybeans-Oats-Hay[2]	Lime + Phosphate	66.3	36.6	320	60
Corn-Soybeans Wheat-Hay	Lime + Phosphate	128.3	46.0	640	70
Corn-Oats-Wheat-Hay	Lime + Fertilizer; farmed parallel to field border	43.4	30.9	1,280	80
Corn-Oats-Wheat-Hay	Lime + Fertilizer; waterways; contoured	1,053.3	76.5	2,560	90
Corn-Oats-Wheat-Hay	Lime + Fertilizer; terraced; contoured	2,333.3	88.2	5,120+	99+
Bluegrass	Lime + Phosphate	6,666.6	99+		

[1] Topsoil about half gone. Crop residues removed from first five plots.
[2] Soybeans before oats in cultivated rows for seed, before wheat was drilled. (Soybeans harvested for hay.)

By using this standard of efficiency, the efficiency of cropping systems at different locations throughout the country may be compared. Two examples of how the efficiency is calculated follow:

1. Time required to erode 7 inches - 27.8 years.

$$\text{Efficiency} = 20\% + \frac{27.8 - 20}{20} \text{ of } 10 = 23.9\%$$

2. Time required to erode 7 inches - 137.0 years.

$$\text{Efficiency} = 40\% + \frac{137.0 - 80}{80} \text{ of } 10 = 47.1\%$$

Page 8. This page should replace page 8.

Attention is called in *table 6* to the 4-year rotation of corn-oats-wheat-hay where farming was carried on parallel to the field boundaries without regard to slope. The efficiency of this system of farming, although lime and fertilizer were used but residues removed, was only 30.9 percent. On the other hand, where this same rotation or cropping system and treatment (except that residues were returned) was followed in combination with contouring and the use of well-established grassed waterways, the efficiency was increased to 76.5 percent. This watershed had only medium length slopes and was well adapted to contouring.

Where terraces were added to the latter system, the efficiency was increased to 88.2 percent. It will also be observed that a 3-year rotation of corn-oats-hay with lime and fertilizer at Bethany, Mo., proved more efficient in controlling erosion than did a 3-year rotation of corn-wheat-hay without treatment. The return of crop residues and manure to the corn-oats-hay plot that was treated raised the efficiency from 50.5 percent to 62.9 percent.

For a rotation of corn-soybeans-wheat-hay where the soybeans were drilled solid and where wheat was seeded as soon as the soybean hay was removed, an efficiency of 46.0 percent is shown, as compared with an efficiency of only 36.6 percent where a rotation of corn-soybeans-oats-hay is used. In the latter rotation soybeans were planted in rows and cultivated and removed for hay. This left the soil bare during the winter and early spring and allowed excessive soil and water losses.

ORGANIC MATTER

Reference was made earlier to the relation of organic matter or nitrogen to crop yields at Bethany, Mo., and Wooster, Ohio, (4). *Table 7, page 9,* shows that with 13 years of corn a total of 4.94 inches of soil were lost and the organic matter had declined from 3.25 percent to 2.23 percent.

Under clean fallow (where the land was turned with a plow each spring and kept cultivated as for corn but no crop planted), the soil loss in 13 years totaled 7.88 inches. The organic matter level of the plow depth (0 to 7 inches) declined from 3.25 to 1.93 percent. Where a 3-year rotation of corn-wheat-hay was practiced without lime and fertilizer or the utilization of crop residues, the soil loss was 0.88 inch and the organic matter remained practically the same as at the beginning of the experiment.

Under 13 years of alfalfa and grass the soil loss was practically nothing--namely, 0.01 inch. The organic matter under alfalfa increased to 3.93 percent and under grass to 3.61 percent. The freshly exposed subsoil in 1930 showed 1.71 percent organic matter in the 0- to 7-inch layer. After 13 years of clean fallow, the organic matter had declined to 1.41 percent. During the 13-year period 5.54 inches of soil were lost.

Under a 4-year rotation that was practiced on an exposed subsoil which was treated with lime and fertilizer and the residues turned under, there was a loss of 1.41 inches of soil, but the organic matter increased to 1.93 percent, a gain of 0.22 percent.

The organic matter distribution by soil depths for the Marshall silt loam near Shenandoah, Iowa, and the Shelby loam near Bethany, Mo., is shown in *table 8, page 9*, (6). In both of these soils the organic matter is markedly higher in the upper 8 inches. This is especially true for the Shelby loam. It will be noted that the Marshall silt loam contained 1.8 percent organic matter in the 24- to 28-inch layer, which was about the same quantity as that found in the Shelby at a depth of 12 to 16 inches. Permeability measurements on these soils show that the Marshall soil transmits water much more rapidly than does the Shelby.

In order to protect land against the many erosion hazards we must provide canopy protection for the land, especially when it is occupied by cultivated crops. *Table 9, page 11,* shows the effect of applied mulch on the yield of corn and soybeans at Urbana, Ill., (4). These are the same plots as those shown in *table 4, page 5,* which showed the protection given against erosion. It was pointed out that keeping crop residues on or near the surface, or adding a straw mulch, markedly reduces erosion. It is therefore important to know what effect this same treatment may have upon crop yields.

TABLE 5.--*Data on soil renewal plots on the Soil and Water Conservation Experiment Station, Bethany, Mo.*

Plot No.	Cropping system	Treatment	Corn yield 1942	Organic matter, 1943	Soil loss 1932-42	Water loss 1932-42
			Bu. per A.	*Percent*	*Inches*	*Inches*
1...	Corn-Oats-Hay-Hay	None, normal soil eroded	43.0	2.84	0.83	42.9
2...	Corn-Oats-Hay-Hay	None, desurfaced soil (subsoil)	20.5	1.93	1.22	48.4
3...	Corn-Oats-Hay-Hay	Lime + phosphate	34.6	1.96	.53	29.7
4...	Corn-Oats-Clover + Timothy	Lime + phosphate	32.2	1.89	.76	39.6
5...	Corn-Oats-Sweet Clover	Lime + phosphate	44.0	2.00	.72	33.0
6...	Corn-Oats-Sweet Clover	Lime + phosphate + manure	64.6	2.26	.62	34.1
7[1]..	Grass-Legume mixture	Lime + phosphate	44.2	2.16	.007	12.1

[1]Plot 7--all residue left on land.

TABLE 6.--*Efficiency of cropping systems, Bethany, Mo., with and without supporting practices for controlling erosion*[1]

Cropping system	Treatment	Time to erode 7 inches - years	Efficiency, Percent
Corn--annually[2]	None	18.8	0.0
Corn--annually	16 tons manure	27.8	32.5
Corn-Wheat-Hay	None	108.2	82.7
Corn-Wheat-Hay	Lime + phosphorus	137.0	86.3
Corn-Oats-Hay	Lime + phosphorus	167.8	88.8
Corn-Oats-Hay	Lime + phosphorus + manure	413.5	95.5
Corn-Soybeans-Oats-Hay[3]	Lime + phosphorus	66.3	71.7
Corn-Soybeans-Wheat-Hay	Lime + phosphorus	128.3	85.4
Corn-Oats-Wheat-Hay	Lime + fertilizer, farmed field B	43.4	56.8
Corn-Oats-Wheat-Hay	Lime + fertilizer, contoured	1,053.8	98.2
Corn-Oats-Wheat-Hay	Lime + fertilizer, terraced and contoured	2,333.3	99.2

[1]Efficiency = $\frac{\text{Soil loss for continuous corn—Soil loss for cropping system}}{\text{Soil loss for continuous corn, no treatment}}$

[2]Plots 1 and 2--Topsoil about half gone. Plot 3 was virgin sod before start of experiment.

[3]Soybeans before oats in cultivated rows for seed, before wheat was drilled. (Soybeans harvested for hay).

$$\text{Efficiency} = \frac{\text{Soil loss under continuous corn minus total soil loss for the cropping system under measurement}}{\text{Total soil loss for continuous corn}}$$

Attention is called in table 6, page 7, to the 4-year rotation of corn-oats-wheat-hay where farming was carried on with the field boundaries without regard to slope. The efficiency of this system of farming was but 56.8 percent. On the other hand, where this same rotation or cropping system was followed in combination with contouring and the use of well-established grassed waterways, the efficiency was increased to 98.2 percent.

Where terraces were added to the same system, the efficiency was increased to 99.2 percent. It will also be observed that a 3-year rotation of corn-oats-hay at Bethany, Mo., proved more efficient in controlling erosion than did a 3-year rotation of corn-wheat-hay. This was partly due to the fact that in the former rotation all residues remained on the land while in the latter they were removed. For a rotation of corn, soybeans, wheat-hay where the soybeans were drilled solid and where wheat was seeded as soon as the soybean hay was removed, an efficiency of 85.4 percent was shown--as compared with an efficiency of but 71.7 percent where a rotation of corn, soybeans, oats, and hay was used. In the latter rotation soybeans were planted in rows and cultivated and removed for grain. This left the soil bare during the winter and early spring and allowed excessive soil and water losses.

ORGANIC MATTER

Reference was made earlier to the relationship of organic matter or nitrogen to the crop yields at Bethany, Mo., and at Wooster, Ohio (4). Table 7, page 9, shows that after 13 years of corn, a total of 4.94 inches of soil was lost and the organic matter had declined from 3.25 percent to 2.23 percent.

Under clean fallow which offered no surface protection, the soil loss in the 13 years totaled 7.88 inches. The organic matter level of the plow depth declined from 3.25 percent to 1.93 percent. Where a 3-year rotation of corn, wheat, and hay was practiced, the soil loss was 0.88 inch and the organic matter remained practically the same as at the beginning of the experiment.

Under 13 years of alfalfa and grass the soil loss was practically nothing--namely, 0.01 inch. The organic matter under alfalfa increased to 3.93 percent and under grass, to 3.61 percent. The freshly exposed subsoil in 1930 showed 1.71 percent organic matter in the 0- to 7-inch layer. After 13 years of clean fallow the organic matter had declined to 1.41 percent. During the 13-year period 5.54 inches of soil were lost. Under a 4-year rotation that was practiced on the exposed subsoil, which was untreated, there was a loss of 1.41 inches of soil, but the organic matter increased to 1.93 percent.

The organic matter distribution by soil depths for the Marshall silt loam near Shenandoah, Iowa, and the Shelby loam near Bethany, Mo., is shown in table 8, page 9 (6). In both of these soils attention is called to the fact that the high level of organic matter is confined pretty well to the plow depth. This is especially true for the Shelby loam. It will be noted that the Marshall silt loam contained 1.8 percent organic matter in the 24- to 28-inch layer, which was about the same amount as found in the Shelby at a depth of 12 to 16 inches. Permeability measurements on these soils show that the Marshall soil transmits water much more rapidly than does the Shelby.

In order to protect land against the many erosion hazards we must provide canopy protection for the land, especially when it is occupied by cultivated crops. Table 9, page 11, shows the effect of applied mulch on the yield of corn and soybeans at Urbana, Ill., (4). These are the same plots as those shown in table 4, page 5, which showed the protection given against erosion. It was pointed out that keeping crop residues on or near the surface, or adding a straw mulch, markedly reduces erosion. It is therefore important to know what effect this same treatment may have upon crop yields.

TABLE 7.--*Organic matter in plow depth, surface and desurfaced soil under different cropping systems, Bethany, Mo.*

SURFACE SOIL

Plot No.	Description and treatment	Organic matter	Soil loss
		Percent	*Acre-inches*
2....	13 yrs. corn annually	2.23	4.94
3....	13 yrs. 3-yr. rotation, no tr.	3.23	.88
7....	13 yrs. alfalfa, L + P	3.93	.01
8....	13 yrs. grass--no tr.	3.61	.01
9....	13 yrs. clean fallow, no tr.	1.93	7.88

DESURFACED SOIL

Plot No.	Description and treatment	Organic matter	Soil loss
10....	Freshly exposed--1930	1.71	-
10....	13 yrs. clean fallow	1.41	5.54
2....	12 yrs. 4-yr. rotation--no tr.	1.93	1.38
7....	Grass legume mix.--L + fert.	2.16	.01
6....	12 yrs. 3-yr. rotation--L + fert. + M	2.26	.70
8....	4 yrs. corn--8 yrs. oats + lesp. + L + fert. + M.	2.15	.20

TABLE 8.--*Organic matter for different soil depths, comparing Marshall silt loam with Shelby loam*

Marshall silt loam		Shelby loam	
Soil depth	Percent	Soil depth	Percent
Inches		*Inches*	
0 - 4	3.4	0 - 4	3.6
4 - 8	3.4	4 - 8	3.6
8 - 12	3.1	8 - 12	2.3
12 - 16	2.6	12 - 16	1.7
16 - 20	2.5	16 - 20	1.5
20 - 24	2.0	20 - 24	1.2
24 - 28	1.8	24 - 28	.8
28 - 32	.6	28 - 32	.4

The data show the yield of corn for 1943 was practically the same for mulch and no mulch. For the other 2 years there was a marked decline in the corn yields where the straw mulch was used, so that for the 3-year period there was a difference of 16.2 bushels in favor of the "no-mulch" areas.

For soybeans the mulched plot averaged 2.3 bushels higher than the "no mulch." There was little difference in the yield of hay. Table 10, page 11, shows the corn yields from different depths of topsoil for a number of locations in Region 3 for 1938, 1939, and 1940 (6). It will be noted, for example, at Bethany that the corn yield for those areas in the fields that had 13 or more inches of topsoil was 67.5 bushels per acre. Where therewereless than 7 inches and more than 5, the yield averaged 43.7 bushels, while where practically all the topsoil was gone the yield was only 15.2 inches. The average for the field was 43.4 bushels per acre.

At Fowler, Ind., in 1939 the average corn yield for areas having 13 or more inches of topsoil was 93.4 bushels per acre, while where there was from 1 to 2 inches of topsoil the yield averaged 49.2 bushels. At the same location in 1940 corn yields were not as high but the yields for those areas having more than 13 inches of topsoil was 69.5 bushels per acre, while the yield for those areas where practically all the topsoil was gone was 19.8 bushels per acre.

The results at Shenandoah and Greenfield, Iowa, show the same type of reductions. In every case, yield reductions began with the loss of the first inch of topsoil. The reductions in yield seem to grow larger, however, as the depth of topsoil becomes less and less.

Similar reductions in yield have been observed for other locations and for other crops. The data all emphasize the fact that since yield declines begin with the loss of the first inch of soil, we must initiate soil and water conservation practices, which of course include the application of soil and water conservation rotations, while plenty of topsoil remains. This is important because the process of rebuilding organic matter and restoring per-acre yields is very slow and expensive.

In summary, I would like to point out that rotations for soil and water conservation must:

1. Supply cover or protection of the proper kind and amount at the time when it is most needed.

2. Condition the soil with vigorous-growing grasses and legumes to resist erosion when clean-tilled crops are grown--also include cover crops to supply organic matter and as near year-round protection as possible.

3. Include use of soil amendments and fertilizers, as high fertility is necessary for effective erosion control, maintenance of organic matter, and economic production.

4. Provide for best use of crop residues, manure, and cover crops, especially while land is in row crops.

5. Include other needed supporting soil and water conservation practices, such as contouring, strip cropping, and terracing.

TABLE 9.--*Effect of applied mulch on yields of corn and soybeans*[1]

Corn yield--grain per acre			Soybeans--seed per acre		Soybean hay per acre	
Year	Mulch (Bushels	No mulch (Bushels)	Mulch (Bushels)	No mulch (Bushels)	Mulch (Tons)	No mulch (Tons)
1941	81.1	90.5	-	-	3.28	2.64
1942	55.1	92.5	36.2	37.4	3.05	3.73
1943	93.2	95.1	26.8	21.0	-	-
Average	76.5	92.7	31.5	29.2	3.27	3.19
Difference	-16.2		+ 2.3		- .02	

[1]Experiment carried out at Urbana, Ill.

TABLE 10.--*Corn yields in bushels per acre from different depths of topsoil for different locations in Region 3, for 1938-40*

Depth of topsoil, inches	Bethany, Mo. Av. 7 fields 1940	Fowler, Ind. Av. 16 fields 1939	Fowler, Ind. Av. 18 fields 1940	Shenandoah, Ia. Av. 10 fields 1939	Greenfield, Ia. Av. 12 fields 1938
13 +	67.5	93.4	69.5	-	-
11 - 12	57.8	88.6	62.4	119.9	63.9
9 - 10	55.4	82.3	56.8	109.0	58.1
7 - 8	50.4	73.4	53.1	92.7	45.8
5 - 6	43.7	66.7	47.0	79.6	42.8
3 - 4	35.4	58.3	39.2	65.4	38.4
1 - 2	24.9	49.2	30.0	52.3	31.8
0 - 1	15.2	-	19.8	-	-
Average	43.4	74.5	54.6	81.7	42.6

Data were secured by Operations and Research technicians of the Soil Conservation Service in cooperation with State Agricultural Experiment Stations.

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